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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

The Four Cycle Oil Engine

Its Operating Principles and Lubrication

PUBLISHED MONTHLY BY
THE TEXAS COMPANY, U.S.A.
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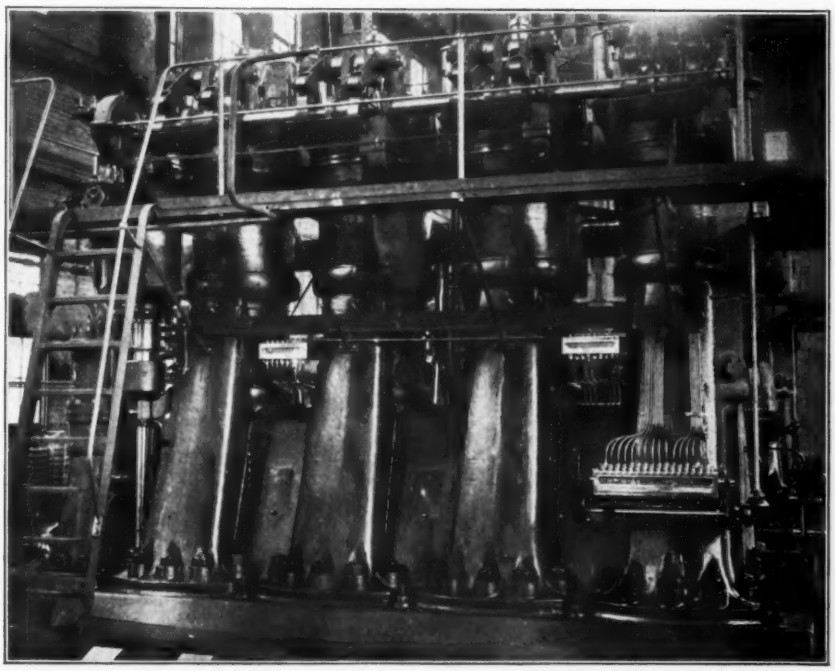


Courtesy of McIntosh & Seymour Corp.

Fig. 1.—Side elevation of a modern four-cycle Diesel engine showing force feed lubricators, sight feeds, and oil leads to the various parts.

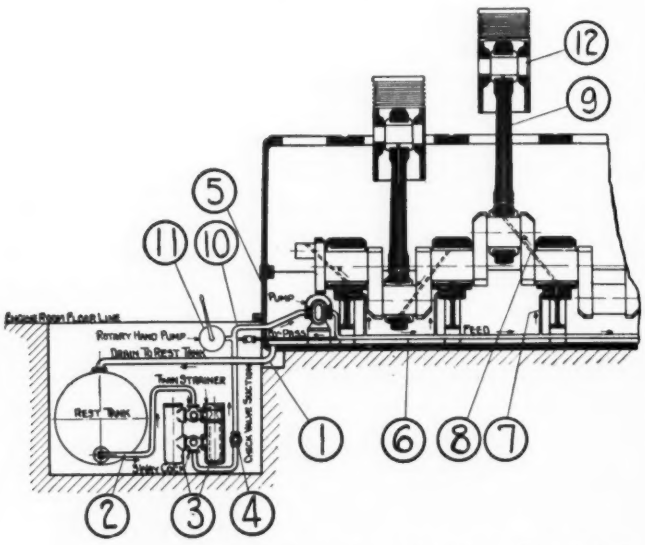
The Four-Cycle Oil Engine

Its Operating Principles and Lubrication

IN the discussion of the operation and lubrication of the two-cycle oil engine which appeared in the December, 1924 issue of LUBRICATION, it was brought out that the fuel, the lubricating oil and the cooling water were the salient factors requiring consideration. The latter two were discussed in greatest detail, especially from the viewpoint of cylinder lubrication, for in the two-cycle oil engine, the essential problem is to so lubricate that the

higher cylinder temperatures involved will be counteracted as much as possible by the lubricating film, and the cooling water.

Of course, to a considerable extent, many of the points brought out in connection with the two-cycle engine will be quite as applicable to the four-cycle. Take the matter of the fuel, for instance. The essential requirements will be the same, even though the manner of combustion and the number of engine operations or strokes involved may differ. So in following this study of the four-cycle engine it will be advisable to bear in mind this similarity, and of interest to note the essential differences involved. This can be readily accomplished by reference to our previous article already mentioned.



Courtesy of Busch-Sulzer Bros.—Diesel Engine Co.

Fig. 2.—Schematic chart of a pressure lubricating system; 1: is the return oil line; 2: the rest tank; 3: the twin strainers; 4 a check valve; 5, 6, 7, 8 and 10, the respective oil piping or oil ways; 9 the connecting rod; 11 a rotary hand pump; and 12 the wrist pin.

The original Diesel patents which were based on the combustion of fuels within the engine, ignition being brought about by the heat of compressed air, involved the four-cycle principle. In other words, four complete strokes of the piston from one end of the cylinder to the other were necessary in the attainment of a complete working cycle. Since that time, however, the oil engine has passed through a stage of development which has proven that the four-cycle type is also adaptable to the semi-Diesel engine wherein ignition is brought about by means of a hot bulb, plate or some other similar method. The full Diesel principle is more extensively employed in larger types of four-cycle engines. Its advancement to a place of prominence in the generation of power has been decidedly marked over the past decade. For a moment it is interesting to look into the reason for this.

The oil engine consumes about one-third as much fuel per unit of power developed as does a steam engine of corresponding rating. Furthermore, with rare exceptions, it functions independently of carburetors and other external ignition systems of this nature. Then, the oil engine of today is capable of burning practically any grade of liquid fuel from kerosene to crude oils; especially is this true of the full Diesel type of engine where fuel injection into the cylinder occurs after the upward stroke of the piston has compressed pure air to such a pressure and temperature that the fuel burns as it is sprayed in. Of course, this is also true of the oil burning steam plant, inasmuch as the properly designed oil burner today will burn practically any petroleum or tar product, regardless of its gravity, provided it is preheated to a sufficient extent.

But we must not lose sight of that characteristic difference between steam and oil prime movers, whereby the efficiency of the former increases materially with the size of the unit. In the case of the oil engine, however, the size has little effect on the efficiency. As a result the natural tendency in stationary service especially, is to segregate steam power in large units for the sake of operating economy.

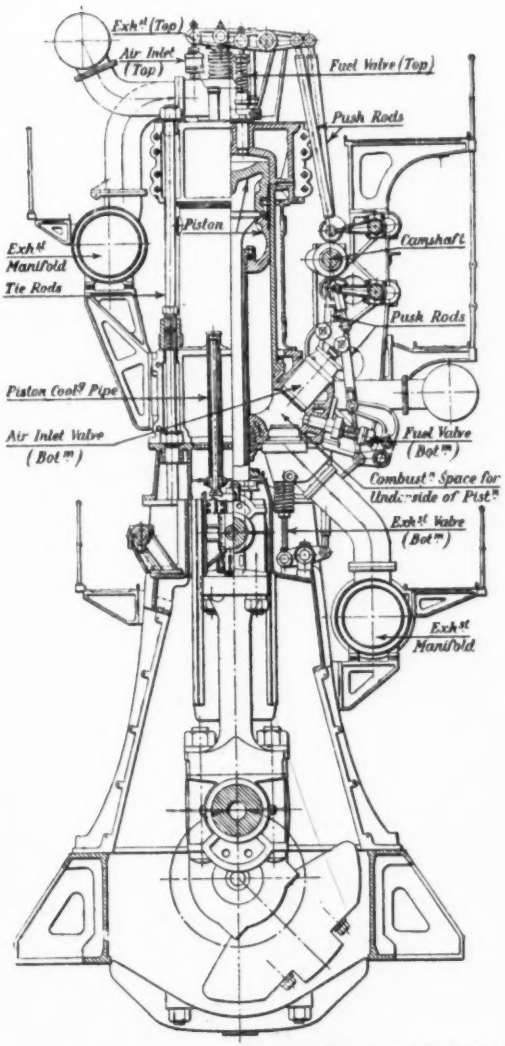
THE PRINCIPLE OF THE FOUR-CYCLE ENGINE

For the benefit of those who may not be intimately conversant with oil engine design, it is deemed advisable to discuss briefly just what this term four-cycle means. Practically speaking it involves the number of times the piston must travel from one end of the cylinder to the other in order to complete the combustion of one charge of fuel. Perhaps it would be more exact, therefore, to refer to it as a four-stroke cycle, but common usage has abbreviated it to the term four-cycle, the matter of strokes being understood as implied.

In the full Diesel engine, these embody essentially:

(1) The *suction stroke*, wherein the piston moves downward or away from the head of the cylinder, to suck in a charge of air through the admission valve which is mechanically opened.

(2) The *compression stroke*, wherein the piston travels upward or back over this path. All the valves are closed during this stroke, consequently the charge of air enclosed within the cylinder is



Courtesy of Burmeister & Wain A/S.

Fig. 3.—Section through a double-acting four-stroke cycle Diesel engine. Each cylinder of this engine is capable of developing over 1100 shaft horse power at 125 R.P.M. An interesting feature is the oil-cooled piston and rod. The rod is fitted with a cast iron liner; between this latter and the steel piston rod is a ring-shaped space through which the oil is carried to the piston. Oil is discharged through the middle of the bored out piston rod.

compressed, the pressure rising to about 500 pounds per square inch. The temperature is thereby raised to the neighborhood of 1000 deg. Fahr., which being above the ignition temperature of the average liquid fuel, will serve to ignite it and bring about complete combustion when the fuel is sprayed in.

(3) The *power stroke*, wherein the piston once again travels downward or away from the cylinder head, when the fuel valve opens simultaneously to spray its charge of oil into the clearance space and combustion chamber. This fuel spray is brought about either by means of air pressure higher than the compression pressure from the air reservoirs, as in the air injection type, or by means of a suitable pump as in the solid or airless injection type. It is interesting to note that contrary to the carburetor type of engine, there is no quick explosion such as would be produced by a spark, and therefore not the same rise in pressure, although the peak will usually be higher. The fuel simply burns to completion, over the period of ignition, the resultant pressure of the gases rising and, after injection ceases, performing work upon the piston to force it once again through its downward stroke. With the exception of the fuel valve which remains open for approximately 1/10 of the stroke, all other valves are closed.

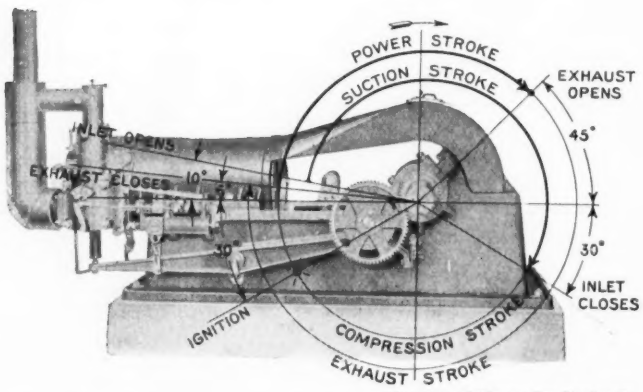
(4) The *exhaust stroke* wherein the piston once more travels upward towards the cylinder head, the exhaust valve opening meanwhile to permit of the expulsion of the exhaust gases.

In effect this operating cycle of the Diesel engine is practically identical with the so-called Otto cycle involved in the automobile engine, with the exception that the method of getting fuel into the cylinder is different. In automobile and all other carburetor types of engines the fuel is mixed and more or less vaporized with the necessary air for combustion before it is drawn into the cylinder on the admission stroke. In the Diesel engine, on the other hand, no fuel is mixed with the air drawn into the cylinder until the beginning of the power stroke, when it is injected in an atomized condition, burning as it is admitted on account of the high temperature within the combustion chamber.

So there is of necessity quite a difference in pressures involved. In the Diesel engine, for example, compression must be great enough to bring about ignition of the fuel when it is injected. Therefore pressures in the neighborhood of 500 pounds per square inch will be customary. To a certain extent this is higher than necessary to actually burn the fuel; as piston rings and cylinders wear, however, compression losses, leakage or "blow-by" will occur to reduce the actual pressures at ignition quite materially. Also a certain amount of cooling occurs when fuel injection takes place.

Higher initial pressures are therefore advisable to compensate for these possible reductions.

The Otto cycle of our typical automobile engine, on the other hand, must guard against pre-ignition, and especially detonation: hence, the compression must never be great enough to ignite the mixture of fuel and air. In general, this cycle will therefore involve pressures ranging from 60 to 150 pounds per square inch.



Courtesy of Charter Gas Engine Co.

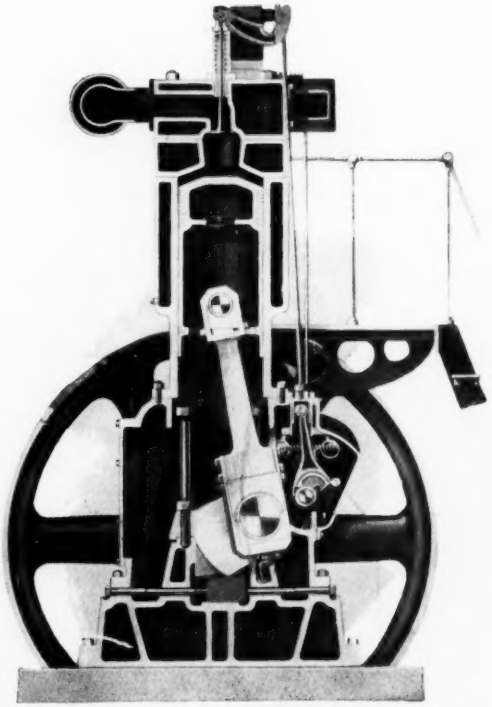
Fig. 4.—Graphical representation of the operating cycles of a four-cycle oil engine. The valve mechanism is operated by two to one gears as shown. One revolution of the valve gear completes the cycle of operation.

This pressure difference which must exist between the two cycles is of decided importance, inasmuch as the thermal efficiency and the power developed from a given quantity of fuel increases for both types of engines as the compression ratio is raised. Theoretically the thermal efficiency of the Otto cycle is higher than that of the Diesel for the same compression ratio. In practice, however, the reverse is true due to the different compressions. It is interesting to look into the reason for this higher theoretical efficiency of the Otto cycle for a given pressure ratio. Essentially this is due to the fact that combustion occurs much more rapidly than with the Diesel engine, causing a considerable rise in pressure and consequently giving a higher ratio between pressure after and before compression. With the Diesel engine, there is only a moderate increase over the compression pressure. The result is that in spite of the high compression of the Diesel engine, the maximum pressure during the cycle is generally but little above that which is frequently attained in high compression Otto engines of the airplane and racing type.

Another interesting point of contrast between these two types of engines is the means by which they are regulated under light loads. In the Diesel engine the quantity of fuel can be reduced as far as desired without affecting the compression ratio. As a result, at light loads the Diesel engine is not subject to as great a proportional increase in fuel consumption as the Otto engine which can operate only with such a quantity of fuel mixed with air as will form an explosive mixture. Also, in the Otto engine these air and fuel mixtures explode only within very narrow percentage limits, and it is not possible to regulate its power output by varying the quantity of fuel used. The air must be varied as well. As a result the compression ratio, and thus the thermal efficiency of the Otto engine is naturally lowered as the loads decrease.

THE FUEL AND ITS EFFECT ON EFFICIENCY

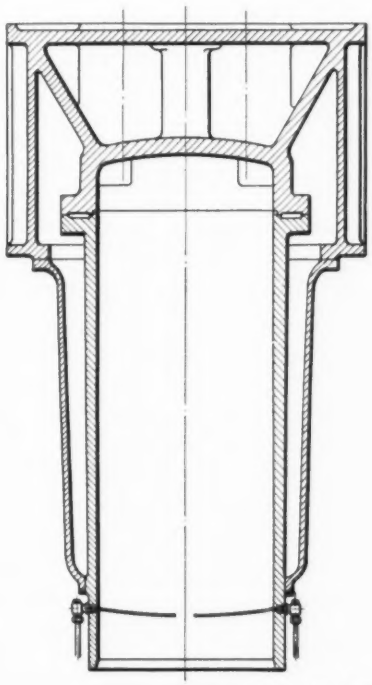
But a Diesel engine can be depended upon to give efficient service only if the fuel used is maintained uniform in quality. We must remember that any oil engine will require a certain amount of adjustment in regard to compression pressure and the details of the spray nozzle, etc., to conform to the nature of the fuel being fired. Mention has already



Courtesy of Ingersoll-Rand Company

Fig. 5.—Vertical section of a solid-injection four-cycle oil engine. The fuel pump which is cam actuated, injects the fuel into the combustion chamber in two sprays which meet in the center of this space, to effectively complete atomization and vaporization. Ignition then takes place automatically due to the heat of compression of the charge of air. The lubricating system in this engine is of the continuous filtration type.

been made in connection with the two-cycle oil engine as to the essential characteristics which a liquid fuel should possess. It will be of further interest, therefore, to look into the types of fuels that are available today, and



Courtesy of Burmeister & Wain A/S.

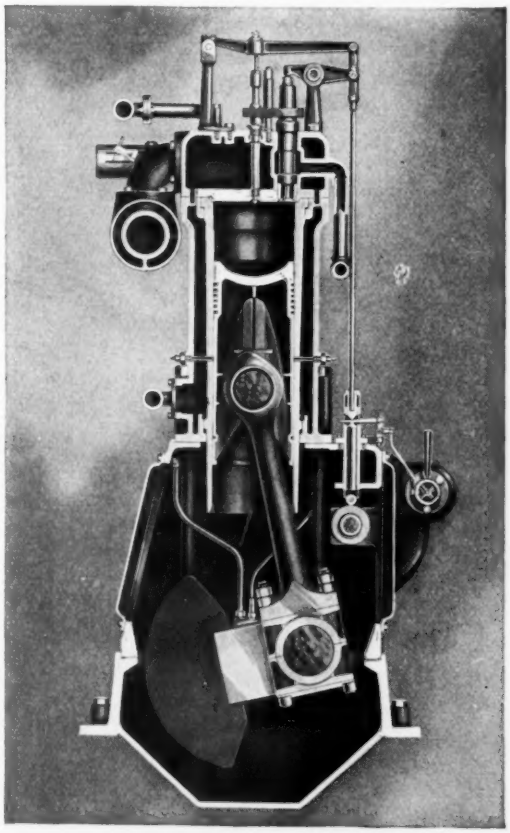
Fig. 6.—Section of a four-cycle Diesel engine cylinder showing the loose liner bolted to the lower surface of the cylinder cover. The large volume of cooling water which is provided for, prevents accumulations of air and scale, insures maximum heat transfer and keeps the oil film on the internal surface of the liner, as cool as possible.

capable, to a more or less extent, of meeting these specifications.

It is a consensus of opinion that liquid fuels for oil engine service can be grouped in three definite classifications. Practically, these are based upon chemical characteristics; on the other hand the suitability of any particular product will include, as well, certain physical properties such as viscosity or relative fluidity, flash point, calorific value, etc.

The first, and today, apparently the most adaptable group of products involve the petroleum or mineral oil series. A scientific definition would further explain them as being compounds of saturated and unsaturated hydro-carbons, containing a high percentage of hydrogen such as do paraffine and naphthenic oils. We state these as being the most adaptable. Whether time will prove this statement, remains to be seen. From a practical viewpoint they are the most readily obtained today in most localities at prices commensurate with the price of coal. Therefore the oil engine is designed to burn them in preference to other products which might give quite as good results, but are economically more or less out of the question. In this same classification we can also group the lignite-tar and shale oils which possess very much the same chemical characteristics. In the combustion of products of this first group, ignition in the present type of oil engine is more readily attained by reason of their comparatively high hydrogen and carbon contents and their volatility or ability to gasify at the operating temperatures involved.

In the second group of available liquid fuels are generally included the products from bituminous coals such as coal tars, and those

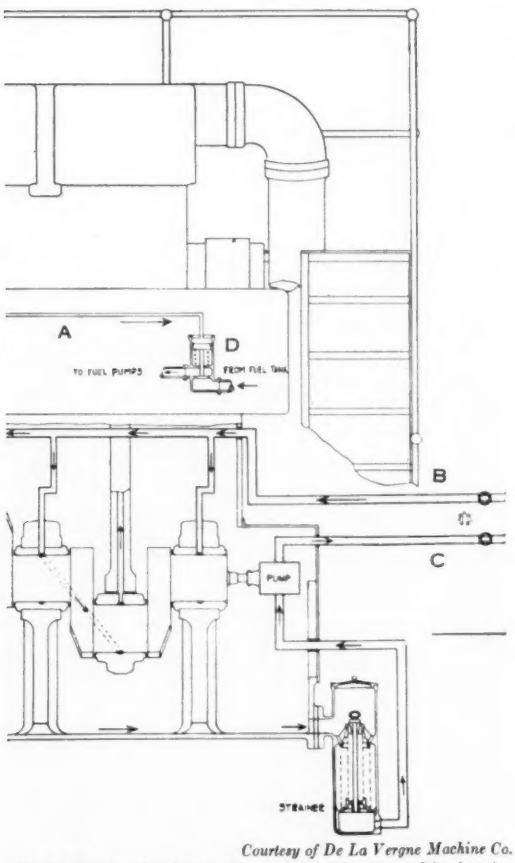


Courtesy of The Bessemer Gas Engine Co.

Fig. 7.—A type of four-cycle, solid injection oil engine which is lubricated by a dual system, i. e., a primary and a secondary. The former includes a mechanical force feed oiler which serves as a cylinder lubricator. The secondary system supplies oil under pressure to all main bearings, crankpin and wristpin bearings.

other products from which benzol is derived. In contrast with petroleum hydrocarbons it is interesting to note that coal tar products and benzols, as a whole, are not entirely suited to combustion in the present type of American oil engine, due to the difficulty with which they

will ignite. For this reason they are often blended with petroleum products to lower their ignition temperature.



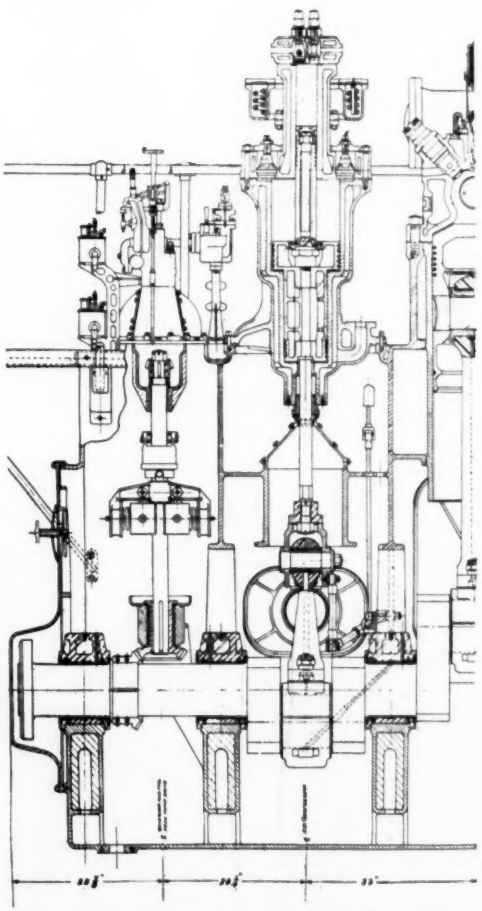
Courtesy of De La Vergne Machine Co.

Fig. 8.—Part-sectional view of a vertical solid-injection Diesel engine with path of lubricating oil indicated by arrows. A unique feature in this engine is the manner in which the lubricating oil is made to control the fuel oil governor as shown, i. e., cessation of flow of the former will cause the fuel oil flow to be stopped automatically. "A" is the extension of the lubricating system, which controls fuel oil governor "D"; "B" is the main lubricating oil distributing header; "C" is the return oil line.

Furthermore, their cost, in comparison with petroleum oils is normally so far out of line, in many localities, that any attempt to adapt the oil engine to burn them would be economically inadvisable at this time. Certain European builders, however, have attempted this, it is understood with considerable success, especially where coal tars have been the fuels involved. Here, of course, comparative fuel costs may be assumed as being the essential reason for this attempted transition.

The third group is composed of vegetable oils such as the products from the castor bean, the soya bean, cottonseed, peanut, etc. While a certain amount of experimentation has been carried out with a view to using these various oils as oil engine fuels, as yet but little advancement has been made. To be true, certain of them have been used to some extent and with a certain amount of success, and it is fair to presume that in the tropics where these oils would be more readily obtainable at fair prices, their usage will become quite practicable provided engines are suitably designed and adjusted, to conform to the usually higher ignition temperatures of these oils.

Whatever the grade of fuel involved, it must be borne in mind that the engine must be adapted to its characteristics, especially as to volatility. In other words, an engine designed or adjusted for one grade of fuel should preferably not be used with another without making adjustments as previously explained.

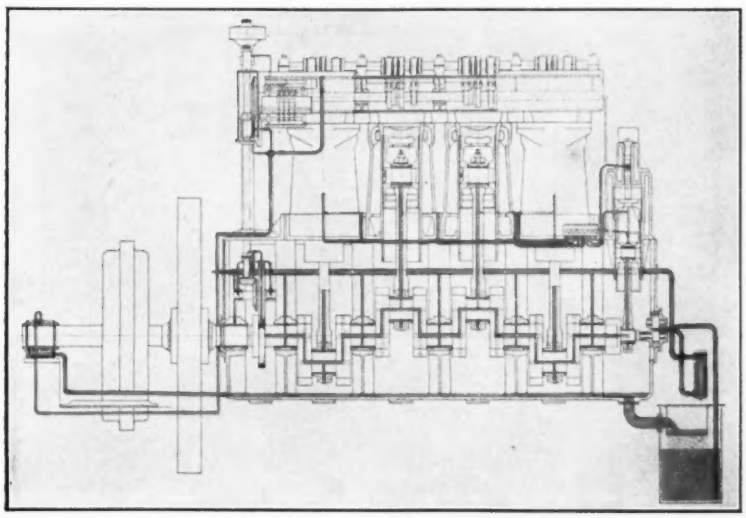


Courtesy of The New London Ship & Engine Co.

Fig. 9.—Part sectional view of a vertical 600 H.P. 6-cylinder, Diesel engine, showing compressor details and one cylinder. This engine is lubricated by pressure feed, the oil flowing by gravity to the main bearings from an overhead tank. Through drilled crankshaft and connecting rods it is further distributed to crank pin and wrist pin bearings. Smaller external parts are either grease or oil lubricated by cups or hand, according to the extent of motion involved.

Probably the greatest problem in an engine unsuited to a grade of fuel is the occurrence of incomplete combustion, with its attendant

possibility of piston rings becoming stuck, and cylinder lubrication and compression being seriously affected. In general the extent to which complete combustion will be attained will depend upon the construction of the fuel valves and atomizers, the intimacy with which the mixing of fuel and air is brought about, and the construction of the cylinder heads or combustion chambers. The heavier and less volatile the fuels, the higher should be the injection pressure to effect complete atomization and mixing with air.



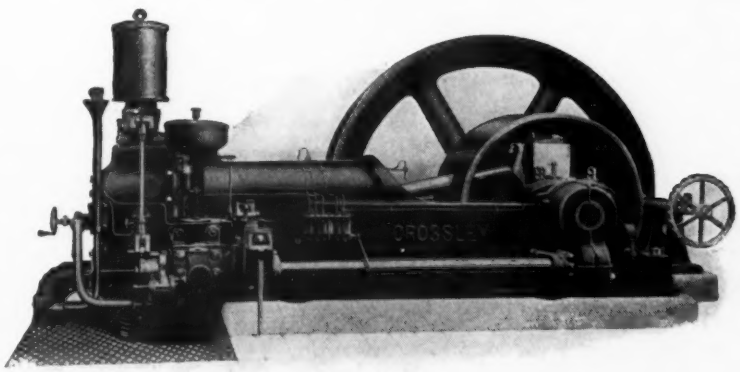
Courtesy of Worthington Pump and Machinery Corp.

Fig. 10—Side elevation in section of a four-cycle air injection engine showing the lubricating oil system and piping in heavy black detail. Note the direct connected oil pump, the strainer tank and independent force feed lubricator to the right of the picture

LUBRICATION AND LUBRICANTS

It has been brought out that efficient lubrication of the engine cylinder will be more or less influenced by the grade of the fuel and the completeness of combustion. This is perhaps the most pertinent problem in the lubrication of the four-cycle engine cylinder. Unlike the two-cycle engine, there is not the heat developed during operation, nor is the lubricant on the cylinder walls subjected to the high velocity and vaporizing action of the exhaust gases, inasmuch as there are no exhaust ports involved, the gases being discharged in a straight line direction via the exhaust valves in the cylinder heads. Furthermore, in the four-cycle engine pressure on the moving parts is not always of the same intensity. According to an eminent authority* in this regard; whereas it may be difficult to get the lubricating oil to spread uniformly over cylinder liner surfaces when the rings are under pressure, we must remember that in the four-cycle engine the pressure on the rings is relieved during the second stroke. As a result the oil is readily spread over the cylinder liner, to materially facilitate the sliding action of the piston and rings during the subsequent strokes of the cycle.

Withal this, however, four-cycle engine cylinder lubrication is important in that it must be positive and uniform, otherwise rings will be worn, or perhaps may become stuck, with an appreciable loss in compression. Too, the wrist-pin will also be affected, even though it may receive its supply of lubricant via the connecting rod or otherwise, for this part of the piston will be subjected to relatively high temperatures with but little opportunity for radiation of its heat unless it is cooled mechanically.

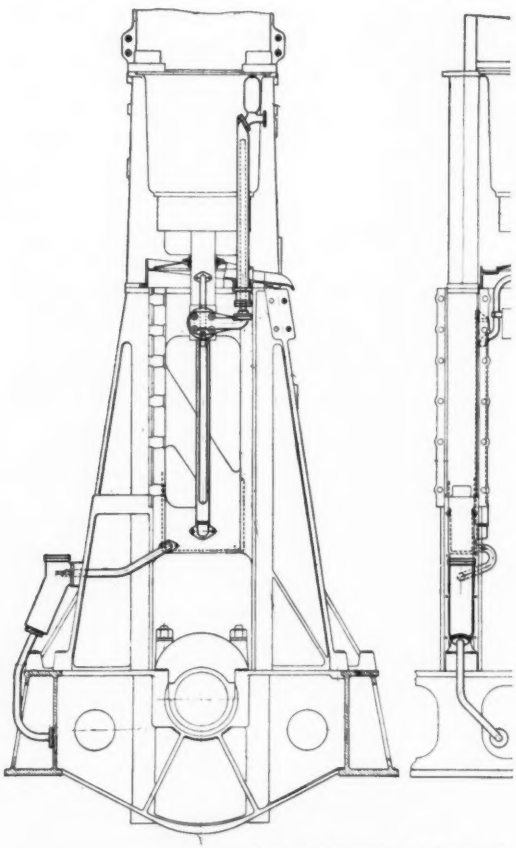


Courtesy of Crossley Bros., Ltd.

Fig. 11.—Side view of a horizontal, airless injection four-cycle oil engine which is capable of operating continuously on very low gravity grades of fuel oil.

*Messrs. Burmeister & Wain A/S, to whom we are indebted likewise for other valued suggestions in the preparation of this article.

To bring about cylinder lubrication most effectively the oil should be delivered regularly to the cylinder and piston by some form of positive lubricator, which will insure a charge of sufficient volume to cover the entire cylinder wall under the swabbing action of the piston.



Courtesy of Burmeister & Wain A/S.

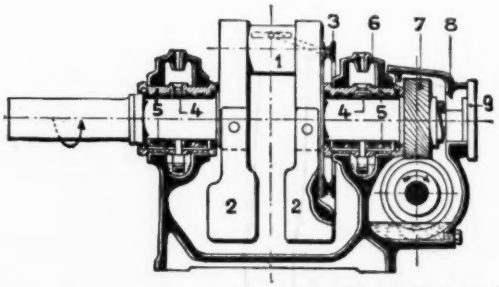
Fig. 12.—Showing the telescopic pipe through which lubricating oil for cooling purposes is carried to each piston of a B & W engine. This pipe is fitted to the end of the cross-head pin so that oil is carried directly from the telescopic pipe through a branch pipe to the hollow piston rod, and not through the cross-head pin and cross-head.

Force feed lubrication is perhaps the most popular means of delivering oil to the cylinder of an oil engine today. Practically speaking, force feed lubrication, as used for cylinders and air compressors, can be regarded as high pressure lubrication, as compared with the relatively low pressure systems used for the miscellaneous bearings of certain types of engines.

Essentially, oil engine lubrication must be positive, and capable of functioning under sufficiently high pressures to withstand the opposing operating pressures. In the air compressor of a full Diesel engine, for example, these would be very high, even though the oil may be delivered at a time when the pressure exerted on the piston is lowest. To function effectively under average pressure conditions, and be spread evenly over the cylinder walls, the lubricant should be delivered to the latter at two or more points. One point of delivery is not considered as dependable, due to the possibility of the opposite side of the cylinder being under-lubricated. In certain cases this can be obviated somewhat by cutting an internal groove in the cylinder wall at the point or points of injection for more even distribution of the oil.

The more even the distribution of the oil, of course, the greater economy of consumption can we expect. As a general rule the four-cycle engine will require less cylinder lubricant than the two-cycle, for the reason that cylinder wall temperatures are not usually as high. Furthermore, the Diesel engine will operate longer on a gallon of oil than a semi-diesel. Conservative estimates figure about 4000 horsepower hours per gallon for the former, as compared with approximately 1000 for the latter, although these will of course vary with the manner in which the engine is operated, the type of lubricating system employed, and the nature and volatility of the oil. Suffice it to say that cylinder oil economy is most important not only from the viewpoint of cost, but also due to the fact that thereby will we prevent possible gumming and carbonizing of the piston rings, blow-by, carbon deposits on the piston head and compression losses.

In other respects, four-cycle oil engine lubrication will be so similar to that of the two-cycle engine that the information already given in connection with the latter,* can be



Courtesy of The Otto Engine Works

Fig. 13.—Crankshaft and bearing details of a four-cycle oil engine: 1, is the crankshaft; 2, the counterweights; 3, the centrifugal oiler ring; 4, the main bearing oiler ring; 5, main bearing boxes; 6, main bearing cap; 7, crankshaft gear; 8, upper gear guard; 9, gear guard cover.

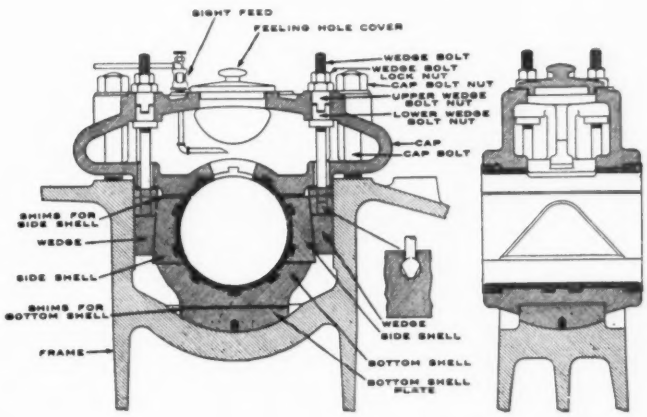
regarded as applicable to both; this, of course, covering essential characteristics of the oils, the lubrication of bearings, etc.

Air Compressor Lubrication

Lubrication of the Diesel engine air compressor is so important as to require individual

*Lubrication, December, 1924.

consideration. In fact, in the air injection type of engine, the air compressor can probably be best regarded as the heart of the system, by virtue of the part it plays in bringing about combustion. To serve this purpose, however, it is absolutely necessary that the compressor



Courtesy of Allis-Chalmers Mfg. Company

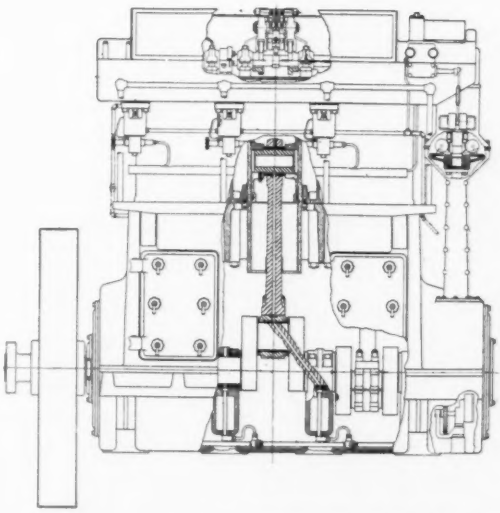
Fig. 14.—Section through the main bearing of a horizontal engine showing constructional details.

be properly lubricated. By this we mean that it should be served with just the right amount of the most suitable grade of oil. Therefore, lubrication may be regarded as one of the secrets of successful compressor operation. As we know, the air compressor as usuallyinstalled in higher powered Diesel engines will generally have three stages, and will be equipped with suitable intercoolers. Now, the compression of air to pressures in the neighborhood of 1000 pounds will of course develop a considerable amount of heat; it is the function of the intercoolers to reduce this heat and thereby keep cylinder temperatures down and reduce the extent of oil vaporization. This is of course in the interests of safety, for otherwise accumulations of dust and carbonaceous matter in the intercoolers, etc., might easily so restrict the air passages as to increase the velocity and consequently the frictional temperature of the air to a dangerous extent. In fact, so-called air compressor explosions are chiefly attributed to such conditions.

While dirty air is perhaps one of the most general causes of such accumulations of foreign matter, we must not forget that an excessive amount of lubricating oil will also tend to develop carbonaceous matter which will materially enhance the accumulation of deposits.

In addition an excess of oil fed to the compressor cylinders may bring about leaky valves due to a certain amount of the oil becoming carbonized on the latter. All this, of course, leads to a decrease in operating efficiency. For this carbonaceous matter being relatively sticky in the early stages of its formation, will also tend to adhere to the piston rings, thereby causing them to become inoperative. The chief danger in the Diesel compressor, however, is that these sticky deposits interfere with the operation of the fuel needle valve, thereby allowing the flame in the engine combustion chamber to pass back through this valve and perhaps cause an explosion in the air lines.

Unfortunately there is no oil which will not deposit some carbon, on the other hand, there is a surprising difference in the nature and quantity of this carbon which will be developed by different oils. Consequently, not only must an oil be most carefully selected, but also, whatever its characteristics, the utmost attention should be paid to prevent the use of more oil than is necessary. In this respect it is very difficult for some operators to realize that but one or two drops of oil per minute is all that is necessary. This is effectively counteracted in many Diesel air

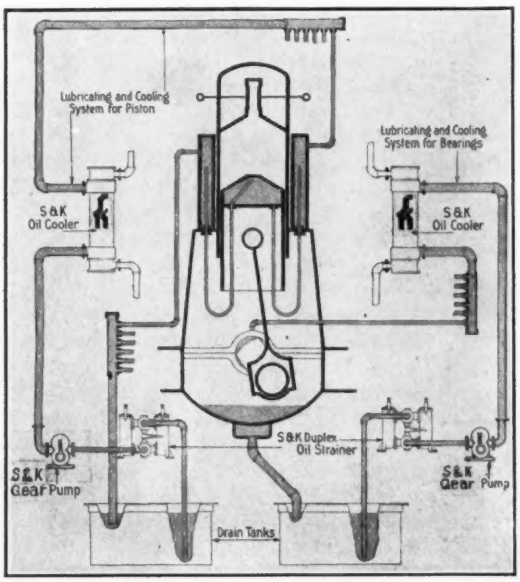


Courtesy of The Foos Gas Engine Co.

Fig. 15.—Details of the lubricating system in a vertical engine whereby essentially all the wearing parts are automatically lubricated. Hand oiling, etc., is thus practically eliminated. The oil in circulation is strained after each tour of duty.

compressors by so designing that the intermediate stage is at the bottom. As a result of such construction there is always a pressure opposing the tendency of the oil to work up into the air space from the lowest cylinder wall where it is thrown by the crankpin.

To best effect air compressor cylinder lubrication, each cylinder should be equipped for force feed or pressure lubrication, whereby uniform and measured quantities of oil can be fed regularly. As has been stated, only a drop or two a minute to the first one or two stages



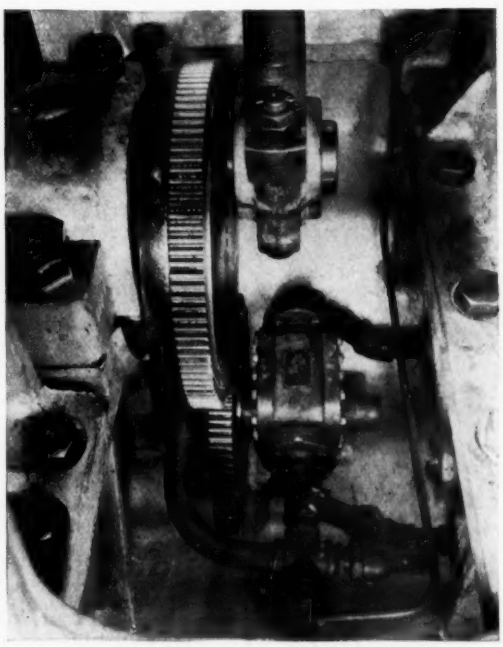
Courtesy of Schutte & Koerting Company

Fig. 16.—Oil cooling and lubricating system for an internal combustion engine. Oil piping and equipment is shown in heavy detail.

will be necessary. The third or last stage will usually be abundantly served with oil carried up from the preceding. On the other hand, no hard and fast rule can be laid down in this regard, and, the safest course to follow in determining upon the quantity of oil to use is to remove the valves at periodic intervals and examine the cylinder walls. A properly lubricated wall should be coated with a film of oil which will just barely dampen or stain a cigarette paper.

This matter of the heat due to compression has caused an unfortunate confusion in the minds of some operators as to the interpretation of the flash points of the lubricating oils for air compressors. Flash point readings are of value only in indicating the relative initial volatility of different oils, and are not definite temperatures at which they "boil" or go completely into vapor corresponding to the boiling point of water. Oils which leave unusually low carbon deposits have lower flash points (and vaporize more readily) than many which leave large deposits. Hence the balance must be drawn between getting a moderate amount of vapor (by virtue of the flashpoint) and very little carbon from the oil, or an appreciable amount of carbon and only a little vapor. The occasional cases of air compressor explosions which have been investigated carefully, suggested that the cause was excessive carbon deposits in the piping, which had greatly restricted the area of the passages. The real cause of these explosions is still to be explained satisfactorily, but it is to be noticed that practically all occurred in piping remote from the compressor, and hence at places not subjected to the highest temperatures. Use of oil made from inferior stocks in a compressor is therefore inadvisable, to say the least, even though it may be cheaper, because of the probability of very high carbon residues.

It is very desirable to clean out the air compressor system at intervals, and wash out the carbon deposits before they grow to large proportions. Kerosene or any similar light oil must under no circumstances be used for this purpose, because of the danger of explosive mixtures due to their high volatility, and the comparatively large quantity used.

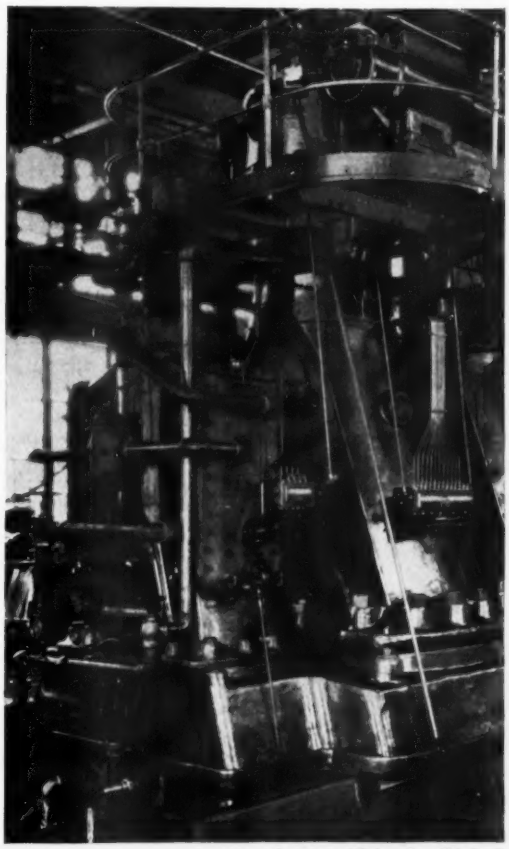


Courtesy of Busch-Sulzer Bros. Diesel Engine Co.

Fig. 17.—A lubricating oil pump located in the crank case of a four-cycle oil engine. This is a positive pressure, gear driven rotary unit, designed to deliver oil to the main, crank and wrist pin bearings under a pressure of from 10 to 15 pounds.

Some operators look with favor on the use of soap suds for cleaning, the solution of soft soap and water being fed into the air intake or through the lubricator about ten times as fast as the usual oil supply. The quantity used must be judged by the amount of carbon found on the valves when they are inspected.

After such an application all receivers must be blown down to remove all the soapy water, and oil used again for a time before shutting down, in order to prevent rusting.



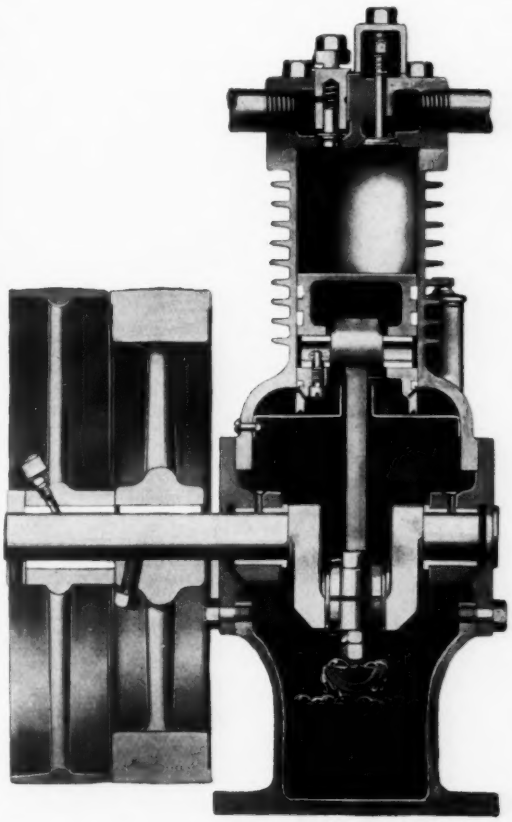
Courtesy of Fulton Iron Works Co.

Fig. 18.—The injection air compressor and one cylinder of a representative four-cycle Diesel engine showing the force feed lubricators and their respective piping. This compressor is of interest in that it is constructed so that all joints are vented to the outside, thus rendering air or water leaks immediately discernible.

THE IMPORTANCE OF CLEAN AIR

Of equal importance with the fuel, lubricants and cooling water, is the air which must be used to bring about combustion. Of course this will be more apparent in the full Diesel engine where air is not only mixed with the fuel prior to combustion, but is also used to bring this about. Yet in the semi-Diesel, it is likewise of importance, for dirty air will preclude efficient operation by increasing deposits and perhaps causing scored cylinders, etc. So it is essential to look into the matter of air cleaning. More detailed discussion of the reasons for this will be of interest. While all air will contain a certain amount of minute abrasive, foreign matter, of course in certain localities and in certain industries this will be far more in evidence than in others. As a general rule the dust content in atmospheric air will vary from 0.10 to 5.0 grains per 1000 cu. ft. according to the extent of draft or wind involved. In fact, in certain industries it may even range above 10.0 grains per 1000 cu. ft. The Marine Diesel engine for example, will usually function on comparatively dust-free air, and therefore might not require any air filtration, whereas, a stationary engine operating in a plant developing considerable dust, etc., would be a decidedly fit candidate for attention in this regard. Essentially, therefore, the oil engine operator will be confronted with the problem of determining the dust content of the air in his engine room.

In the counteraction and partial elimination of deposits and so-called carbonaceous matter in the cylinders, etc., of oil engines and oil

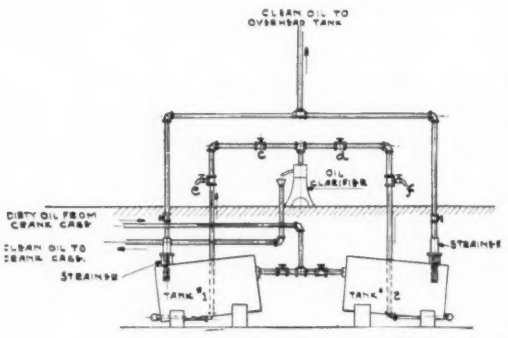


Courtesy of Chicago Pneumatic Tool Co.

Fig. 19.—Cutaway view of an air starting compressor of the single acting type. Note that the bearings and cylinder are splash lubricated. This compressor is driven from the engine by means of a short belt drive.

engine air compressors, it is well to bear in mind that dust and other foreign matter carried in with the air is one of the chief promoters of these evils. In fact the amount of carbon

developed in the normal operation of the average four-cycle Diesel engine using medium gravity fuel and high grade lubricating oil, will usually be practically negligible. This is vividly brought out in marine practice where air is to all intents and purposes practically



Courtesy of Fulton Iron Works Company

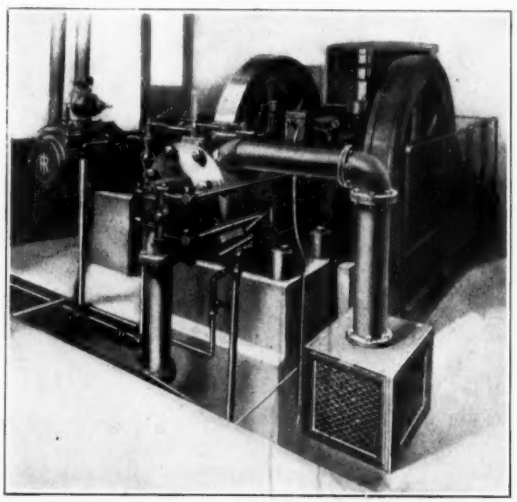
Fig. 20.—Arrangement of lubricating oil piping for a four-cycle oil engine showing strainers, rest tanks and oil clarifier which fits the oil for re-usage.

dust-free; how often will carbon deposits become so excessive in such engines as to involve sealing of the piston rings, pitting of valves, blow-by and losses in compression? To be true, an excess of lubricating oil, or the use of such an oil with an abnormal carbon content, may lead to carbon deposits, but under average operating conditions the bulk of such carbon will probably be burned out during the power stroke.

So it is with the solid, non-combustible matter that we are more distinctly concerned, especially, too, if the fuel as well as the air contains such impurities or is so injected that incomplete combustion takes place. Under such conditions a cementing medium would be developed or left as part of the fuel residue which would soon absorb any dust and dirt carried in with the air, and collect on the piston heads, the walls of the combustion chamber, and even around the rings. The use of an excess of lubricating oil would increase the percentage of potential gummy residue, and not only aid in the formation of deposits but also tend to seal the rings. It is conceivable that dust and dirt might have a certain catalytic action in this regard, for as is true in the automobile engine, cylinder deposits are noticeably increased when dirty air is used. In other words the dirt and dust carried in by the air prevents the burning out of true carbonaceous residues during operation.

CONCLUSION

Inasmuch as space limitations have precluded the extensive discussion which this important subject of the four-cycle oil engine warrants, effort has been made through the medium of representative illustrations to set forth the more salient features of design and construction which have played such a part in bringing the oil engine to the front as a means of power generation. For the matter of selection of prime moving equipment is a problem. The steam engine has its inherent advantages, just as does the oil engine. It is not our province to compare these advantages. It is, however, our mission to set forth the basic features of design and operation, and the requirements from a fuel and lubricating point of view. This we have done in the past, in regard to the steam engine and steam turbine.



Courtesy of Midwest Air Filters, Inc.

Fig. 21.—Clean air is a decided adjunct to efficient oil engine operation. An air filter, as shown above, is therefore a requisite wherever the air may contain an abnormal amount of dust or other foreign matter.

This we again attempt in the interests of the four-cycle oil engine. If the reader is able to profit thereby, to the attainment of better power economy, a reduction in his fuel bills and more efficient production, our purpose will have been fulfilled.

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